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Aggregation, Heterogeneous Autoregression and Volatility of Daily International Tourist Arrivals and Exchange Rates

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Abstract

Tourism is a major source of service receipts for many countries, including Taiwan. The two leading tourism countries for Taiwan, comprising a high proportion of world tourist arrivals to Taiwan, are Japan and USA, which are sources of short and long haul tourism, respectively. As it is well known that a strong domestic currency can have adverse effects on international tourist arrivals, daily data from 1 January 1990 to 31 December 2008 are used to model the world price and US$ / New Taiwan $ and Yen/ New Taiwan $ exchange rates, and tourist arrivals from the world, USA and Japan to Taiwan, as well as their associated volatility. The sample period includes the Asian economic and financial crises in 1997, and part of the global financial crisis of 2008-09. Inclusion of the exchange rate allows approximate daily price effects on world, US and Japanese tourist arrivals to Taiwan to be captured. The Heterogeneous Autoregressive (HAR) model does not reproduce the theoretical hyperbolic decay rates associated with fractionally integrated (or long memory) time series models, but it can nevertheless approximate quite accurately and parsimoniously the slowly decaying correlations associated with such models. The HAR model is used to approximate long memory properties in daily exchange rates and international tourist arrivals, to test whether alternative short and long run estimates of conditional volatility are sensitive to the approximate long memory in the conditional mean, to examine asymmetry and leverage in volatility, and to examine the effects of temporal and spatial aggregation. The empirical results show that the conditional volatility estimates are not sensitive to the approximate long memory nature of the conditional mean specifications. The QMLE for the GARCH(1,1), GJR(1,1) and EGARCH(1,1) models for world, US and Japanese tourist arrivals to Taiwan, and the world price and US$ / New Taiwan $ and Yen/ New Taiwan $ exchange rates, are statistically adequate and have sensible interpretations. Asymmetry (though not leverage) is found for several alternative HAR models for the world, US and Japanese tourist arrivals to Taiwan. For policy purposes, these empirical results suggest that an arbitrary choice of data frequency or spatial aggregation will not lead to robust findings as they are generally not independent of the level of aggregation used.

Keywords: International tourist arrivals, exchange rates, global financial crisis, GARCH, GJR, EGARCH, HAR, approximate long memory, temporal aggregation, spatial aggregation, daily effects, weekly effects, asymmetry, leverage.

JEL Classifications: C22, F31, G18, G32.

1. Introduction

Tourism is a major source of service receipts for many countries, including Taiwan. The main island of Taiwan, which consists of steep mountains covered by tropical and subtropical vegetation, is also known as Formosa (from the Portuguese *Ilha Formosa*, meaning “beautiful island”). The population in 2005 was 23 million inhabitants, consisting predominantly of Han Chinese. The climate of Taiwan is marine tropical, with the northern part of the island having a rainy season from January to late March during the southwest monsoon. The island succumbs to hot and humid weather from June until September, while October to December is arguably the most pleasant time of the year, although it can be quite cool. Natural hazards, such as typhoons and earthquakes, are common in the East Asia region, and can have devastating effects, as seen in the devastating typhoons that struck the island in 2009.

The two leading tourism countries for Taiwan, comprising a high proportion of world tourist arrivals to Taiwan, are Japan and USA, which are sources of short and long haul tourism, respectively. Although more than three million international tourists visited Taiwan in 2008, the major part of the Taiwan tourist industry is supported by domestic tourism. Taiwan’s extensive network of trains and highways makes it possible to traverse the country (north-south) in less than two hours by the new high speed train, and in a few hours by car. The most well known tourist attractions in Taiwan include the spectacular National Palace Museum (Taipei), home to some of Chinese greatest antiquities, the amazing Night Markets throughout the country, Taipei 101, formerly the world’s tallest building, relaxing Sun Moon Lake (near Puli in the central highlands), and stunning Taroko National Park in Hualian on the east coast.

A major purpose in tourism marketing is to increase total tourism expenditure receipts. If the daily expenditure per international tourist were to be reasonably constant over the sample period, then international tourist arrivals and total international tourism expenditure would be highly correlated. Moreover, the rate of growth in daily international tourism expenditure and the rate of growth in daily international tourist arrivals would then be virtually identical.

As it is well known that a strong domestic currency can have adverse effects on international tourist arrivals, one of the primary purposes of the paper is to model daily tourist arrivals to Taiwan from the world, USA and Japan, and the world price and US$ / New Taiwan $ and Yen/ New Taiwan $ exchange rates, and their respective volatilities. Daily data from 1 January 1990 to 31 December

2008 are obtained from the National Immigration Agency of Taiwan for daily world, US and Japanese tourist arrivals, the Bloomberg database for the two foreign exchange rates, and the Reuters database for the world price.

In order to manage international tourist arrivals from the major tourism sources, as well as tourism growth and its corresponding volatility, it is necessary to model adequately international tourist arrivals and their associated volatility, especially in the presence of significant economic and financial shocks. In light of the 2008-09 global financial crisis, its significant economic impact on the tourism industry in Taiwan and internationally, and the need for a speedy and informative analysis of the level of international tourist arrivals, their growth rates and associated volatility, it is essential to use daily data rather than the usual monthly, quarterly or annual data that have traditionally been used in previous empirical tourism studies.

Daily data permit an appeal to the theoretical results available in financial econometrics, and an approximation of the modelling and forecasting strategies widely used in financial time series analysis. From a time series perspective, there are several reasons for using daily data rather than lower frequencies such as monthly, quarterly or annual data (see, for example, McAleer (2009)). In addition to the use of much larger sample sizes than those associated with monthly, quarterly or annual data, the use of daily data permits an examination of whether the time series properties have changed. The time series behaviour at other temporal frequencies, such as weekly data, can be obtained by aggregation of daily data, so that temporal aggregation effects can be analysed. Moreover, approximate daily price elasticities of the demand for international tourism can be estimated through the use of daily exchange rates, and the daily volatility of international tourism demand and exchange rates can be analysed. The use of daily data enables more immediate responses to be activated in light of generating daily estimates and forecasts of approximate price effects through the exchange rate, and accurate daily forecasts of tourist arrivals and their growth rates, in response to significant economic and financial shocks. In addition, the estimation and forecasting of time-varying conditional volatilities will enable more accurate confidence intervals for international tourist arrivals and their growth rates to be determined on a daily basis.

The empirical results show that the time series of world, US and Japanese tourist arrivals to Taiwan, and the world price and US$ / New Taiwan $ and Yen / New Taiwan $ exchange rates, are stationary. In addition, the estimated symmetric and asymmetric conditional volatility models, specifically the widely used univariate GARCH, GJR and EGARCH models, all fit the data very well. In particular, the estimated models are able to account for the higher volatility persistence in world, US and Japanese tourist arrivals, and the world price and two exchange rates, that are observed at the end of the sample period due to the global financial crisis. The empirical second moment conditions support the statistical adequacy of the empirical models for world, US and Japanese tourist arrivals, so that statistical inferences are valid. Moreover, the estimates resemble those arising from financial time series data, with both short and long run persistence of shocks to world, US and Japanese tourist arrivals, and asymmetric responses to positive and negative shocks of equal magnitude, though no leverage effects are observed. Therefore, volatility can be interpreted as risk associated with the growth rate in world, US and Japanese tourist arrivals to Taiwan.

The remainder of the paper is organized as follows. Section 2 presents the daily world, US and Japanese tourist arrivals, world price and exchange rate time series data. Section 3 performs unit root tests on the three tourist arrivals series for daily and weekly data. Section 4 discusses approximate long memory conditional mean and conditional volatility models for daily world, US and Japanese tourist arrivals, world price and two exchange rates. The estimated models and empirical results for the heterogeneous autoregressive (HAR) and three univariate conditional volatility models are discussed in Section 5, as are the effects of temporal aggregation from daily to weekly data. Finally, some concluding remarks are given in Section 6.

2. Data

The data set comprises daily tourist arrivals from the world, USA and Japan for the period 1 January 1990 to 31 December 2008, giving 6,940 observations obtained from the National Immigration Agency of Taiwan, and an equivalent number of observations for the US$ / New Taiwan $ and Yen/ New Taiwan $ exchange rates, that are obtained from the Bloomberg database: Taipei Foreign Exchange Market Development Foundation (URL: http://www.tpefx.com.tw). The world price is obtained from Reuters as the Intercontinental Exchange calculation of the US Dollar Index, which is the US $ relative to a geometric weighted mean of six currencies (namely, Euro, Canadian $, Japanese yen, Swedish krona, Pound sterling and Swiss franc). Thus, if the US $ increases relative to the world price, then prices in the USA will be lower, thereby leading to reduced US tourists to Taiwan. Moreover, the higher world price will have a positive income effect for the rest of the world, which will tend to increase world tourist arrivals to Taiwan. Overall, the world price effect on world tourist arrivals to Taiwan would be expected to be negative.

Figures 1-4 plot the daily and weekly tourist arrivals from the world, USA and Japan, and the world price and US$ / New Taiwan $ and Yen/ New Taiwan $ exchange rates, as well as their respective volatilities, where volatility is defined as the squared deviation from the sample mean. There is higher volatility persistence at the end of the sample period, due primarily to the global financial crisis (for further details on the global financial crisis see, for example, McAleer (2009) and McAleer et al. (2009, 2009a, 2009b, 2010)).

Daily and weekly tourist arrivals to Taiwan from the world, USA and Japan, and the corresponding daily and weekly exchange rates, have varied considerably over the sample period, which suggests that the daily and weekly effects of the approximate price movements on international tourism demand might be captured using appropriate heterogeneous time series and conditional volatility models. The exchange rate effects aside, there would seem to be considerable scope for a significant increase in tourism to Taiwan from the world, USA and Japan.

In the next section we analyze the presence of a stochastic trend by applying unit root tests before modelling the time-varying volatility that is present in daily and weekly tourist arrivals to Taiwan from the world, USA and Japan.

3. Unit Root Tests

Standard unit root tests based on the classic methods of Dickey and Fuller (1979, 1981) and Phillips and Perron (1988) are available in the econometric software package EViews 6.0, and are reported in Table 1. There is no evidence of a unit root in daily or weekly world, US and Japanese tourist arrivals to Taiwan in the model with a constant and trend as the deterministic terms, or with just a constant. Thus, the daily and weekly series to be modeled are stationary at standard significance levels.

These empirical results allow the use of world, US and Japanese tourist arrivals data to Taiwan, and the three exchange rates, to estimate alternative univariate approximate long memory conditional mean and conditional volatility models given in the next section. Before doing so, it is useful to examine which daily exchange rates should be used for their weekly counterparts. Table 2 gives the correlation coefficients for the world price and Japanese and US exchange rates for the arithmetic and geometric means of the seven daily prices and exchange rates, as well as for the seven days of the week, for purposes of selecting the appropriate world weekly price and weekly exchange rates for Japan and USA. It is clear that the correlation coefficients are very close to one in all cases, and that the arithmetic and geometric means are identical to three decimal places. For this reason, the arithmetic means of the seven daily world prices and exchange rates are chosen as the respective weekly prices and weekly exchange rates for the world, Japan and USA.

4. Conditional Mean and Conditional Volatility Models

The alternative time series models to be estimated for the conditional means of daily and weekly world, US and Japanese tourist arrivals to Taiwan, as well as their respective conditional volatilities, are discussed below. As shown in Figures 1-4, both daily and weekly world, US and Japanese tourist arrivals to Taiwan and the three exchange rates show periods of high volatility, followed by others of relatively low volatility. One implication of this persistent volatility behaviour is that the assumption of (conditionally) homoskedastic residuals is inappropriate.

As discussed in Divino and McAleer (2009, 2010) and Chang and McAleer (2009), for example, for a wide range of data series in finance, international finance and tourism research, time-varying conditional variances can be explained empirically through the autoregressive conditional heteroskedasticity (ARCH) model (Engle (1982)). When the time-varying conditional variance has both autoregressive and moving average components, this leads to the generalized ARCH(p,q), or GARCH(p,q) (Bollerslev (1986)). The lag structure of the appropriate GARCH model can be chosen by information criteria, such as those of Akaike and Schwarz, although it is very common to impose the widely estimated GARCH(1,1) specification in advance.

In the selected conditional volatility model, the residual series should follow a white noise process. Li et al. (2002) provide an extensive review of theoretical results for univariate and multivariate time series models with conditional volatility errors, and McAleer (2005) reviews a wide range of univariate and multivariate, conditional and stochastic, models of financial volatility. When the daily and weekly world, US and Japanese tourist arrivals data, and the three exchange rate series, display persistence in volatility, as shown in Figures 1-4, it is natural to estimate alternative conditional volatility models.

The GARCH(1,1), GJR(1,1) and EGARCH(1,1) conditional volatility models have been estimated using monthly and daily tourist arrivals data in several papers, including Chan, Lim and McAleer (2005), Hoti, McAleer and Shareef (2005, 2007), Shareef and McAleer (2005, 2007, 2008), Chang et al. (2009), Chang and McAleer (2009), and Divino and McAleer (2009, 2010). However, these papers have not estimated any spillover effects between tourist arrivals and exchange rates using daily and weekly data, and have not examined world price effects, and hence have not been able to capture any approximate price effects affecting tourism demand, or the effects of temporal and spatial aggregation.

The conditional volatility literature has been discussed extensively in recent years (see, for example, Li, Ling and McAleer (2002), McAleer (2005), McAleer, Chan and Marinova (2007), and Caporin and McAleer (2009, 2010)). Consider the stationary AR(1)-GARCH(1,1) model for daily or weekly world, US and Japanese tourist arrivals to Taiwan, y_t:

$$y_t = \phi_1 + \phi_2 y_{t-1} + \varepsilon_t, \qquad |\phi_2| < 1 \tag{1}$$

for $t = 1,...,n$, where the shocks (that is, movements in international tourist arrivals are given by:

$$\begin{aligned} \varepsilon_t &= \eta_t \sqrt{h_t}, \quad \eta_t \sim iid(0,1) \\ h_t &= \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}, \end{aligned} \tag{2}$$

and $\omega > 0, \alpha \geq 0, \beta \geq 0$ are sufficient conditions to ensure that the conditional variance $h_t > 0$. The AR(1) model in equation (1) can easily be extended to univariate or multivariate ARMA(*p*,*q*) processes (for further details, see Ling and McAleer (2003a)). In equation (2), the ARCH (or α) effect indicates the short run persistence of shocks, while the GARCH (or β) effect indicates the contribution of shocks to long run persistence (namely, $\alpha + \beta$). The stationary AR(1)-GARCH(1,1) model can be modified to incorporate a non-stationary ARMA(*p*,*q*) conditional mean and a stationary GARCH(*r*,*s*) conditional variance, as in Ling and McAleer (2003b).

In equations (1) and (2), the parameters are typically estimated by the maximum likelihood method to obtain Quasi-Maximum Likelihood Estimators (QMLE) in the absence of normality of η_t, the conditional shocks (or standardized residuals). The conditional log-likelihood function is given as follows:

$$\sum_{t=1}^{n} l_t = -\frac{1}{2}\sum_{t=1}^{n}\left(\log h_t + \frac{\varepsilon_t^2}{h_t}\right).$$

The QMLE is efficient only if η_t is normal, in which case it is the MLE. When η_t is not normal, adaptive estimation can be used to obtain efficient estimators, although this can be computationally intensive. Ling and McAleer (2003b) investigated the properties of adaptive estimators for univariate non-stationary ARMA models with GARCH(*r*,*s*) errors. The extension to multivariate processes is complicated.

As the GARCH process in equation (2) is a function of the unconditional shocks, it is necessary to examine the moments conditions of ε_t. Ling and McAleer (2003a) showed that the QMLE for GARCH(*p*,*q*) is consistent if the second moment of ε_t is finite. For GARCH(*p*,*q*), Ling and Li (1997) demonstrated that the local QMLE is asymptotically normal if the fourth moment of ε_t is finite. Using results from Ling and Li (1997) and Ling and McAleer (2002a, 2002b), the necessary and sufficient condition for the existence of the second moment of ε_t for GARCH(1,1) is $\alpha + \beta < 1$ and, under normality, the necessary and sufficient condition for the existence of the fourth moment is $(\alpha + \beta)^2 + 2\alpha^2 < 1$.

As discussed in McAleer et al. (2007), it was established by Elie and Jeantheau (1995) and Jeantheau (1998) that the log-moment condition was sufficient for consistency of the QMLE of a univariate GARCH(p,q) process (see Lee and Hansen (1994) for an analysis of the GARCH(1,1) process), while Boussama (2000) showed that the log-moment condition was sufficient for asymptotic normality. Based on these theoretical developments, a sufficient condition for the QMLE of GARCH(1,1) to be consistent and asymptotically normal is given by the log-moment condition, namely

$$E(\log(\alpha\eta_t^2 + \beta)) < 0. \qquad (3)$$

However, this condition is not easy to check in practice, even for the GARCH(1,1) model, as it involves the expectation of a function of a random variable and unknown parameters. Although the sufficient moment conditions for consistency and asymptotic normality of the QMLE for the univariate GARCH(1,1) model are stronger than their log-moment counterparts, the second moment condition is more straightforward to check. In practice, the log-moment condition in equation (3) would be estimated by the sample mean, with the parameters α and β, and the standardized residual, η_t, being replaced by their QMLE counterparts.

The effects of positive shocks (or upward movements in daily or weekly international tourist arrivals or exchange rates) on the conditional variance, h_t, are assumed to be the same as the negative shocks (that is, downward movements in daily or weekly international tourist arrivals or exchange rates) in the symmetric GARCH model. In order to accommodate asymmetric behaviour, Glosten, Jagannathan and Runkle (1992) proposed the GJR model, for which GJR(1,1) is defined as follows:

$$h_t = \omega + (\alpha + \gamma I(\eta_{t-1}))\varepsilon_{t-1}^2 + \beta h_{t-1}, \tag{4}$$

where $\omega > 0, \alpha \geq 0, \alpha + \gamma \geq 0, \beta \geq 0$ are sufficient conditions for $h_t > 0,$ and $I(\eta_t)$ is an indicator variable defined by:

$$I(\eta_t) = \begin{cases} 1, & \varepsilon_t < 0 \\ 0, & \varepsilon_t \geq 0 \end{cases}$$

as η_t has the same sign as ε_t. The indicator variable differentiates between positive and negative shocks of equal magnitude, so that asymmetric effects in the data are captured by the coefficient γ.

For financial data, it is expected that $\gamma \geq 0$ because negative shocks increase risk by increasing the debt to equity ratio, but this interpretation need not hold for daily or weekly international tourist arrivals or exchange rates in the absence of a direct risk interpretation. The asymmetric effect, γ, measures the contribution of shocks to both short run persistence, $\alpha + \frac{\gamma}{2}$, and to long run persistence, $\alpha + \beta + \frac{\gamma}{2}$. It is not possible for leverage to be present in the GJR model, whereby negative shocks increase volatility and positive shocks of equal magnitude decrease volatility.

Ling and McAleer (2002a) showed that the regularity condition for the existence of the second moment for GJR(1,1) under symmetry of η_t is given by:

$$\alpha + \beta + \frac{1}{2}\gamma < 1, \qquad (5)$$

while McAleer et al. (2007) showed that the weaker log-moment condition for GJR(1,1) was given by:

$$E(\ln[(\alpha + \gamma I(\eta_t))\eta_t^2 + \beta]) < 0, \qquad (6)$$

which involves the expectation of a function of a random variable and unknown parameters.

An alternative model to capture asymmetric behaviour in the conditional variance is the Exponential GARCH (EGARCH(1,1)) model of Nelson (1991), namely:

$$\log h_t = \omega + \alpha \mid \eta_{t-1} \mid + \gamma \eta_{t-1} + \beta \log h_{t-1}, \quad \mid \beta \mid < 1 \qquad (7)$$

where the parameters α , β and γ have different interpretations from those in the GARCH(1,1) and GJR(1,1) models. If γ = 0, there is no asymmetry, while γ < 0, and γ < α < -γ are the conditions for leverage to exist, whereby negative shocks increase volatility and positive shocks of equal magnitude decrease volatility.

As noted in McAleer et al. (2007), there are some important differences between EGARCH and the previous two models, as follows: (i) EGARCH is a model of the logarithm of the conditional variance, which implies that no restrictions on the parameters are required to ensure $h_t > 0$; (ii) moment conditions are required for the GARCH and GJR models as they are dependent on lagged unconditional shocks, whereas EGARCH does not require moment conditions to be established as it depends on lagged conditional shocks (or standardized residuals); (iii) Shephard (1996) observed that $\mid \beta \mid < 1$ is likely to be a sufficient condition for consistency of QMLE for EGARCH(1,1); (iv) as the standardized residuals appear in equation (7), $\mid \beta \mid < 1$ would seem to be a sufficient condition for the existence of moments; and (v) in addition to being a sufficient condition for consistency, $\mid \beta \mid < 1$ is also likely to be sufficient for asymptotic normality of the QMLE of EGARCH(1,1).

Furthermore, EGARCH captures asymmetries differently from GJR. The parameters α and γ in EGARCH(1,1) represent the magnitude (or size) and sign effects of the standardized residuals, respectively, on the conditional variance, whereas α and $\alpha+\gamma$ represent the effects of positive and negative shocks of equal magnitude, respectively, on the conditional variance in GJR(1,1).

5. Heterogeneous Models and Empirical Analysis

The Heterogenous Autoregressive (HAR) model was proposed by Corsi (2009) as an alternative to model and forecast realized volatilities, and is inspired by the Heterogenous Market Hypothesis of Muller, Dacorogna, Dav, Olsen, Pictet, and Ward (1993) and the asymmetric propagation of volatility between long and short horizons. Corsi (2009) showed that the actions of different types of market participants could lead to a restricted autoregressive model with the feature of considering volatilities realized over different time horizons. The heterogeneity of the model derives from the fact that different autoregressive structures are present at each time scale (for further details, see McAleer and Medeiros (2008)).

Although HAR models cannot reproduce the theoretical hyperbolic decay rates associated with fractionally integrated (or long memory) time series models, they can nevertheless approximate quite accurately and parsimoniously the slowly decaying correlations associated with such long memory models. For this reason, HAR models may be interpreted as simple restricted approximations to long memory models.

Alternative HAR models will be used to model international tourist arrivals to Taiwan from the world, USA and Japan, together with three widely used univariate conditional volatility models, namely GARCH, GJR and EGARCH, as discussed in the previous section.

The alternative HAR(*h*) models to be estimated to approximate long memory are based on the following:

$$y_{t,h} = \frac{y_t + y_{t-1} + y_{t-2} + \ldots + y_{t-h+1}}{h} \tag{8}$$

where typical values of *h* are 1 (daily data), 7 (weekly data), and 28 (monthly data). In the empirical application, the three HAR models to be estimated for world, US and Japanese daily tourist arrivals to Taiwan are as follows:

$$y_t = \phi_1 + \phi_{21} y_{t-1} + \phi_{22} x_{t-1} + \varepsilon_t \tag{9}$$

$$y_t = \phi_1 + \phi_{21} y_{t-1} + \phi_{22} x_{t-1} + \phi_{31} y_{t-1,7} + \phi_{32} x_{t-1,7} + \varepsilon_t \tag{10}$$

$$y_t = \phi_1 + \phi_{21} y_{t-1} + \phi_{22} x_{t-1} + \phi_{31} y_{t-1,7} + \phi_{32} x_{t-1,7} + \phi_{41} y_{t-1,28} + \phi_{42} x_{t-1,28} + \varepsilon_t \tag{11}$$

and the two HAR models to be estimated for world, US and Japanese weekly tourist arrivals to Taiwan are as follows:

$$y_t = \phi_1 + \phi_{21} y_{t-1} + \phi_{22} x_{t-1} + \varepsilon_t \tag{12}$$

$$y_t = \phi_1 + \phi_{21} y_{t-1} + \phi_{22} x_{t-1} + \phi_{31} y_{t-1,4} + \phi_{32} x_{t-1,4} + \varepsilon_t \ . \tag{13}$$

The models in equations (9)-(11) will be referred to as the HAR(1), HAR(1,7) and HAR(1,7,28) models, respectively, and those in equations (12)-(13) as the HAR(1) and HAR(1,4) models, respectively. The two sets of models in (9)-(11) and (12)-(13) will enable an assessment of the effects of temporal aggregation from the daily to weekly data frequency. Moreover, a comparison of the model of world tourist arrivals to Taiwan with those of US and Japanese tourist arrivals to Taiwan will enable an examination of spatial aggregation effects on the HAR estimates, short and long run persistence of shocks on tourist arrivals, the exchange rate effects, and the empirical regularity conditions.

The estimated conditional mean and conditional volatility models for the world, Japan and USA are given in Tables 3-11 for daily data and in Tables 12-17 for weekly data. The method used in estimation was the Marquardt algorithm. The conditional mean estimates in Tables 3-17 show that the HAR(1), HAR(1,7) and HAR(1,7,28) estimates for daily data, and the HAR(1) and HAR(1,4) estimates for weekly data, are all statistically significant. Thus, the approximate long memory properties of world, Japanese and US tourist arrivals to Taiwan are captured adequately through the statistical significance of the approximate long memory variables.

Table 18 summarizes the HAR effects under temporal aggregation for daily and weekly lags. Apart from the HAR(1,7,28) model for daily lags in the case of world tourist arrivals, the HAR lag lengths of 1, 7 and 28 are always significant for daily tourist arrivals for the world, Japan and USA, and the HAR lag lengths of 1 and 4 are always significant for weekly tourist arrivals for the world, Japan and USA. Therefore, HAR effects do not seem to be sensitive to temporal aggregation.

As shown in the unit root tests in Table 1, the world, Japanese and US tourist arrivals to Taiwan series are stationary. These empirical results are supported by the estimates of the lagged dependent variables in the estimates of equations (9)-(11) for international tourist arrivals, with the coefficients of the lagged dependent variable being significantly less than one in each of the estimated models.

As the second moment conditions for the GARCH(1,1) and GJR(1,1) models are less than unity in each case, the log-moment conditions are also necessarily satisfied. Thus, the regularity conditions are satisfied, and hence the QMLE are consistent and asymptotically normal, and inferences are valid. The EGARCH(1,1) model is based on the standardized residuals, so the regularity condition is satisfied if $|\beta| < 1$, and hence the QMLE are consistent and asymptotically normal (see, for example, McAleer et al. (2007)).

The GARCH(1,1) estimates in Tables 3-17 for the HAR(1), HAR(1,7) and HAR(1,7,28) models of world, Japanese and US tourist arrivals to Taiwan suggest that the short and long run persistence of shocks for daily data lie between (0.220, 0.261) and (0.243, 0.429), respectively, for the world, between (0.256, 0.326) and (0.418, 0.489), respectively, for Japan, and between ((0.051, 0.054) and (0.980, 0,984), respectively, for USA. The corresponding short and long run persistence of shocks for weekly data lie between (0.348, 0.411) and (0.441, 0.541), respectively, for the world, between (0.104, 0.108) and (0.854, 0.861), respectively, for Japan, and between ((0.343, 0.352) and (0.579, 0.650), respectively, for USA. Thus, the range of estimates for the short and long run persistence of shocks differs according to the world and the two leading tourism sources to Taiwan, which reflects the importance of spatial aggregation, as well as the data frequency, which reflects the importance of temporal aggregation.

If positive and negative shocks to world, Japanese and US tourist arrivals to Taiwan of a similar magnitude are treated asymmetrically, this can be evaluated in the GJR(1,1) model. As can be seen in Table 19, asymmetry (though not leverage) was found in 7 of 9 cases for daily data for the world, Japan and USA, and asymmetry (though not leverage) was found in 4 of 6 cases for weekly data. Therefore, shocks to world, Japanese and US tourist arrivals to Taiwan can be interpreted as risk associated with the corresponding tourist arrivals. Although asymmetry is observed for the HAR(1) model for the world, and for the HAR(1), HAR(1,7) and HAR(1,7,28) models for Japan and the USA, for daily data, and for the HAR(1) and HAR(1,4) models for the world and USA for weekly data, there is no evidence of leverage. Moreover, the three HAR models suggest asymmetry for Japan using daily data, but changes to symmetry for Japan using two models for weekly data. Thus, these empirical results show that a determination of symmetry or asymmetry arising from the conditional volatility models is sensitive to the temporal aggregation of daily to weekly data.

As the second moment condition, $\alpha + \beta + \frac{1}{2}\gamma < 1$, is typically satisfied, the log-moment condition is necessarily satisfied, so that the QMLE for the GJR(1,1) model are consistent and asymptotically normal. Therefore, statistical inference using the asymptotic normal distribution is valid, and the asymmetric GJR(1,1) estimates are statistically significant.

The interpretation of the EGARCH model is in terms of the logarithm of volatility. For daily and weekly world, Japanese and US tourist arrivals to Taiwan, the EGARCH(1,1) estimates were generally statistically significant for the various HAR models, with the size effect, α, and sign effect, γ, typically being significant. The coefficient of the lagged dependent variable, β, is estimated to be less than unity, which suggests that the statistical properties of the QMLE for EGARCH(1,1) will be consistent and asymptotically normal.

As can be seen in Table 20, the world price and exchange rate effects are always negative for the HAR(1) model for daily and weekly data, and are also generally negative for the HAR(1,7) and HAR(1,7,28) models for daily data and HAR(1,4) model for weekly data. The expected negative price and exchange rate effects generally do not change with temporal aggregation.

In summary, the QMLE for the GARCH(1,1), GJR(1,1) and EGARCH(1,1) models for daily and weekly world, Japanese and US tourist arrivals to Taiwan are statistically adequate and have sensible interpretations. The empirical results also show that the volatility in the shocks to daily and weekly world, Japanese and US tourist arrivals to Taiwan can be sensitive to the long memory nature of the conditional mean specifications.

6. Concluding Remarks

Although tourism is not yet one of the most important service industries in Taiwan, tourist arrivals from Japan and USA, the two most important source countries for Taiwan, reflect an increasing demand for short and long haul tourist travel. World tourist arrivals to Taiwan have been growing steadily, and reflect the spatial aggregation of numerous tourism source countries. However, there is significant room for improvement in tourism receipts from the various tourism source countries.

The potential negative impacts of mass tourism on the environment, and hence on future world, Japanese and US tourism demand, must be managed appropriately. In order to manage such tourism growth, it is necessary to model adequately world, Japanese and US tourist arrivals and their associated volatility. As the exchange rate allows approximate daily price effects on Japanese and US tourism arrivals to Taiwan to be captured, it is also necessary to analyse the Yen / New Taiwan $ and US$ / New Taiwan $ exchange rates, and the world price, as well as their associated volatilities.

The paper examined daily and weekly world, Japanese and US tourist arrivals to Taiwan from 1 January 1990 to 31 December 2008, and the world price and Yen / New Taiwan $ and US$ / New Taiwan $ exchange rates. The Heterogeneous Autoregressive (HAR) model was used to capture the approximate long memory properties in the tourist arrivals series. The empirical results showed that the time series of world, Japanese and US tourist arrivals to Taiwan, and the world price and two exchange rates, were stationary. In addition, the estimated symmetric and asymmetric conditional volatility models, specifically the widely used GARCH, GJR and EGARCH models all fit the data extremely well. In particular, the estimated models were able to account for the higher volatility persistence that was observed at the end of the sample period, due primarily to the global financial crisis.

The empirical second moment condition also generally supported the statistical adequacy of the models of world, Japanese and US tourist arrivals to Taiwan, so that statistical inferences were valid. Moreover, the estimates resembled those arising from financial time series data, with both short and long run persistence of shocks, and asymmetric effects of positive and negative shocks of equal magnitude to volatility. Although asymmetry was observed for the HAR models using daily and weekly data, there was no evidence of leverage. Overall, volatility could be interpreted as risk associated with shocks to world, Japanese and US tourist arrivals to Taiwan.

With regard to the effects of temporal and spatial aggregation, it was found that HAR effects did not seem to be sensitive to temporal aggregation, a determination of symmetry or asymmetry arising from the conditional volatility models was sensitive to the temporal aggregation of daily to weekly data, the expected negative price and exchange rate effects generally did not change with temporal aggregation, and the range of estimates for the short and long run persistence of shocks were different for the world, Japan and USA. Thus, both spatial aggregation and the data frequency, or temporal aggregation, were found to be important for estimating the dynamic effects of world prices and exchange rates, and their respective volatilities, on world, Japanese and US tourist arrivals to Taiwan.

For policy purposes, these empirical results suggest that an arbitrary choice of data frequency or spatial aggregation will not lead to robust findings as they are generally not independent of the level of aggregation used. Thus, a careful analysis of different levels of temporal and spatial aggregation needs to be undertaken to obtain sensible estimates, regularity conditions, short and long run persistence of shocks to tourist arrivals, asymmetry and leverage effects, and the negative effects of the world price and exchange rates on international tourist arrivals.

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Table 1. Unit Root Tests

Variables	ADF Z={1}	PP Z={1}	ADF Z={1,t}	PP Z={1,t}
Daily World Tourist Arrivals to Taiwan	-3.164*	-58.939**	-5.445**	-78.257**
Daily Japanese Tourist Arrivals to Taiwan	-5.491**	-65.306**	-6.330**	-64.594**
Daily US Tourist Arrivals to Taiwan	-4.648**	-71.519**	-7.100**	-81.346**
Variables	**ADF Z={1}**	**PP Z={1}**	**ADF Z={1,t}**	**PP Z={1,t}**
Weekly World Tourist Arrivals to Taiwan	-2.161	-8.825**	-4.252**	-16.211**
Weekly Japanese Tourist Arrivals to Taiwan	-3.540**	-19.530**	-4.434**	-21.092**
Weekly US Tourist Arrivals to Taiwan	-4.648**	-10.358**	-8.135**	-14.719**

Notes: The critical values for the ADF test are -3.43 (-2.86) at the 1% (5%) level when Z = {1}, and -3.95 (-3.41) at the 1% (5%) level when Z = {1, t}. The critical values for the PP test are -3.43 (-2.86) at the 1% (5%) level when Z = {1}, and -3.95 (-3.41) at the 1% (5%) level when Z = {1, t}.
** and * denote the null hypothesis of a unit root is rejected at the 1% and 5% levels, respectively.

Table 2. Correlation Coefficients for World Price and Exchange Rates

World Price / US$

Variable	W_A	W_G	W_Su	W_Mo	W_Tu	W_We	W_Th	W_Fr	W_Sa
W_A	1	1.000	0.998	0.999	0.999	0.999	0.999	0.999	0.999
W_G	1.000	1	0.998	0.999	0.999	0.999	0.999	0.999	0.999
W_Su	0.998	0.998	1	0.999	0.998	0.997	0.996	0.995	0.995
W_Mo	0.999	0.999	0.999	1	0.999	0.998	0.997	0.996	0.996
W_Tu	0.999	0.999	0.998	0.999	1	0.999	0.998	0.997	0.997
W_We	0.999	0.999	0.997	0.998	0.999	1	0.999	0.998	0.998
W_Th	0.999	0.999	0.996	0.997	0.998	0.999	1	0.999	0.999
W_Fr	0.999	0.999	0.995	0.996	0.997	0.998	0.999	1	1.000
W_Sa	0.999	0.999	0.995	0.996	0.997	0.998	0.999	1.000	1

Yen / New Taiwan $

Variable	JP_A	JP_G	JP_Su	JP_Mo	JP_Tu	JP_We	JP_Th	JP_Fr	JP_Sa
JP_A	1	1.000	0.998	0.999	0.999	0.100	0.999	0.999	0.999
JP_G	1.000	1	0.998	0.999	0.999	0.100	0.999	0.999	0.999
JP_Su	0.998	0.998	1	0.999	0.998	0.997	0.997	0.996	0.996
JP_Mo	0.999	0.999	0.999	1	0.999	0.998	0.997	0.996	0.996
JP_Tu	0.999	0.999	0.998	0.999	1	0.999	0.998	0.997	0.997
JP_We	0.100	0.100	0.997	0.998	0.999	1	0.999	0.998	0.998
JP_TH	0.999	0.999	0.997	0.997	0.998	0.999	1	0.999	0.999
JP_Fr	0.999	0.999	0.996	0.996	0.997	0.998	0.999	1	1.000
JP_Sa	0.999	0.999	0.996	0.996	0.997	0.998	0.999	1.000	1

US$ / New Taiwan $

Variable	US_A	US_G	US_Su	US_Mo	US_Tu	US_We	US_Th	US_Fr	US_Sa
US_A	1	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000
US_G	1.000	1	0.999	1.000	1.000	1.000	1.000	1.000	1.000
US_Su	0.999	0.999	1	1.000	0.999	1.000	1.000	0.999	0.999
US_Mo	1.000	1.000	1.000	1	1.000	0.999	0.999	0.999	0.999
US_Tu	1.000	1.000	0.999	1.000	1	1.000	1.000	0.999	0.999
US_We	1.000	1.000	0.999	0.999	1.000	1	1.000	1.000	1.000
US_Th	1.000	1.000	0.999	0.999	1.000	1.000	1	1.000	1.000
US_Fr	1.000	1.000	0.999	0.999	1.000	1.000	1.000	1	1.000
US_Sa	1.000	1.000	0.999	0.999	1.000	1.000	1.000	1.000	1

Notes: The entries refer to the arithmetic mean (A), geometirc mean (G), and the seven days of each week for purposes of selecting the appropriate weekly exchange rate. Correlation coefficients of 1.000 are rounded upward.

Table 3: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for World Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	1393.2*** (122.1)	1300*** (118.6)	1303.6*** (118.4)
ϕ_{21}	0.816*** (0.008)	0.824*** (0.007)	0.830*** (0.007)
ϕ_{22}	-3.178*** (1.047)	-3.082*** (1.007)	-3.620*** (0.999)
ω	899965*** (29091)	852835*** (29755)	11.317*** (0.555)
GARCH/GJR α	0.220*** (0.013)	0.135*** (0.009)	--
GARCH/GJR β	0.023 (0.022)	0.044* (0.025)	--
GJR γ	--	0.259*** (0.038)	--
EGARCH α	--	--	0.438*** (0.020)
EGARCH γ	--	--	-0.116*** (0.016)
EGARCH β	--	--	0.164*** (0.040)
Diagnostics			
AIC	16.776	16.769	16.769
BIC	16.782	16.777	16.776
Jarque-Bera [p-value]	1828.80 [0.000]	1285.23 [0.000]	1306.88 [0.000]
Causality *t* test [p-value]	-3.036 [0.002]	-3.059 [0.002]	-3.625 [0.0003]

Notes: The dependent variable is world daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 10% levels, respectively.

Table 4: Estimated Conditional Mean (HAR(1,7)) and Conditional Volatility Models for World Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	374.20*** (116.9)	374.25*** (117.2)	319.01*** (113.9)
ϕ_{21}	0.288*** (0.014)	0.285*** (0.014)	0.299*** (0.013)
ϕ_{22}	2.961 (18.72)	2.943 (18.74)	0.889 (18.17)
ϕ_{31}	0.659*** (0.015)	0.662*** (0.015)	0.650*** (0.015)
ϕ_{32}	-3.833 (18.67)8	-3.785 (18.69)	-1.274 (18.13)
ω	548393** (22475)	543330*** (22913)	8.786*** (0.427)
GARCH/GJR α	0.261*** (0.015)	0.270*** (0.017)	--
GARCH/GJR β	0.168*** (0.026)	0.175*** (0.026)	--
GJR γ	--	-0.024 (0.029)	--
EGARCH α	--	--	0.463*** (0.021)
EGARCH γ	--	--	0.008 (0.014)
EGARCH β	--	--	0.333*** (0.031)
Diagnostics			
AIC	16.537	16.537	16.539
BIC	16.545	16.546	16.548
Jarque-Bera [p-value]	1713.20 [0.000]	1680.71 [0.000]	1576.06 [0.000]
Causality *F* test [p-value]	0.409 [0.664]	0.382 [0.683]	0.083 [0.920]

Notes: The dependent variable is world daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficient is statistically significant at the 1% level.

Table 5: Estimated Conditional Mean (HAR(1,7,28)) and Conditional Volatility Models for World DailyTourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	183.94 (120.55)	184.44 (121.17)	162.34 (114.41)
ϕ_{21}	0.287*** (0.014)	0.285*** (0.014)	0.300*** (0.013)
ϕ_{22}	13.349 (19.249)	13.180 (19.357)	14.413 (10.619)
ϕ_{31}	0.460*** (0.021)	0.461*** (0.021)	0.450*** (0.020)
ϕ_{32}	-0.585 (25.042)	-0.568 (25.057)	4.032 (10.683)
ϕ_{41}	0.225*** (0.020)	0.225*** (0.020)	0.224*** (0.018)
ϕ_{42}	-12.947 (11.736)	-12.960 (11.746)	-15.754 (8.273)
ω	558469*** (21559)	556273*** (21846)	9.337*** (0.440)
GARCH/GJR α	0.261*** (0.014)	0.264*** (0.017)	--
GARCH/GJR β	0.149*** (0.025)	0.152*** (0.025)	--
GJR γ	--	-0.011 (0.029)	--
EGARCH α	--	--	0.463*** (0.020)
EGARCH γ	--	--	0.001 (0.014)
EGARCH β	--	--	0.292*** (0.032)
Diagnostics			
AIC	16.523	16.524	16.525
BIC	16.533	16.535	16.536
Jarque-Bera [p-value]	1903.05 [0.000]	1886.77 [0.000]	1828.80 [0.000]
Causality F test [p-value]	0.775 [0.508]	0.774 [0.509]	1.896 [0.150]

Notes: The dependent variable is world daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors.
The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficients are statistically significant at the 1% level.

Table 6: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for Japanese Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	1126.3*** (53.04)	1094.2*** (52.30)	1101.1*** (53.33)
ϕ_{21}	0.672*** (0.009)	0.682*** (0.009)	0.674*** (0.009)
ϕ_{22}	-82.00*** (11.486)	-74.53*** (11.59)	-71.459*** (11.83)
ω	246509*** (13137)	222585*** (12750)	5.372*** (0.392)
GARCH/GJR α	0.256*** (0.015)	0.363*** (0.024)	--
GARCH/GJR β	0.162*** (0.033)	0.242*** (0.033)	--
GJR γ	--	-0.284*** (0.026)	--
EGARCH α	--	--	0.326*** (0.018)
EGARCH γ	--	--	0.160*** (0.012)
EGARCH β	--	--	0.563*** (0.031)
Diagnostics			
AIC	15.726	15.713	15.719
BIC	15.732	15.720	15.726
Jarque-Bera [p-value]	694.00 [0.000]	599.97 [0.000]	580.31 [0.000]
Causality *t* test [p-value]	-7.139 [0.000]	-6.430 [0.000]	-6.043 [0.000]

Notes: The dependent variable is Japanese daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors.
The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficients are statistically significant at the 1% level .

Table 7: Estimated Conditional Mean (HAR(1,7)) and Conditional Volatility Models for Japanese Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	481.28*** (58.13)	511.88*** (57.35)	498.73*** (56.08)
ϕ_{21}	0.428*** (0.013)	0.434*** (0.013)	0.422*** (0.013)
ϕ_{22}	-199.74 (209.08)	-227.85 (210.24)	-212.49 (202.46)
ϕ_{31}	0.435*** (0.016)	0.426*** (0.016)	0.441*** (0.016)
ϕ_{32}	159.72 (208.61)	185.84 (209.88)	172.76 (202.43)
ω	207729*** (10272)	197091*** (9587.6)	5.843*** (0.335)
GARCH/GJR α	0.313*** (0.016)	0.439*** (0.025)	--
GARCH/GJR β	0.171*** (0.028)	0.223*** (0.026)	--
GJR γ	--	-0.334*** (0.029)	--
EGARCH α	--	--	0.423*** (0.021)
EGARCH γ	--	--	0.169*** (0.014)
EGARCH β	--	--	0.517*** (0.026)
Diagnostics			
AIC	15.636	15.621	15.626
BIC	15.644	15.630	15.635
Jarque-Bera [p-value]	1112.4 [0.000]	784.72 [0.000]	768.78 [0.000]
Causality F test [p-value]	6.488 [0.002]	7.301 [0.001]	6.855 [0.001]

Notes: The dependent variable is Japanese daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficient is statistically significant at the 1% level.

Table 8: Estimated Conditional Mean (HAR(1,7,28)) and Conditional Volatility Models for Japanese Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	292.48*** (63.78)	319.97*** (63.45)	306.59*** (60.73)
ϕ_{21}	0.420*** (0.013)	0.424*** (0.013)	0.413*** (0.013)
ϕ_{22}	-296.39 (215.39)	-314.61 (216.23)	-279.64 (210.03)
ϕ_{31}	0.278*** (0.021)	0.278*** (0.021)	0.270*** (0.021)
ϕ_{32}	328.05 (295.43)	313.67 (296.86)	289.94 (286.33)
ϕ_{41}	0.228*** (0.022)	0.222*** (0.022)	0.244*** (0.022)
ϕ_{42}	-64.794 (147.72)	-33.51 (150.13)	-43.96 (141.73)
ω	204415*** (9621)	197127*** (8962.8)	6.157*** (0.321)
GARCH/GJR α	0.326*** (0.017)	0.456*** (0.025)	--
GARCH/GJR β	0.163 (0.026)***	0.204*** (0.024)	--
GJR γ	--	-0.339*** (0.030)	--
EGARCH α	--	--	0.451*** (0.022)
EGARCH γ	--	--	0.168*** (0.015)
EGARCH β	--	--	0.490*** (0.025)
Diagnostics			
AIC	15.620	15.606	15.609
BIC	15.630	15.617	15.619
Jarque-Bera [p-value]	1208.31 [0.000]	837.86 [0.000]	803.45 [0.000]
Causality F test [p-value]	3.256 [0.020]	3.645 [0.012]	3.520 [0.014]

Notes: The dependent variable is Japanese daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficients are statistically significant at the 1% level.

Table 9: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for US Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	816.94*** (26.75)	808.35*** (27.15)	836.05*** (26.06)
ϕ_{21}	0.592*** (0.010)	0.593*** (0.010)	0.588*** (0.010)
ϕ_{22}	-13339*** (632.3)	-13099*** (639.4)	-13746*** (613.87)
ω	603.06*** (78.25)	697.78*** (88.49)	0.098** (0.026)
GARCH/GJR α	0.053*** (0.003)	0.060*** (0.004)	--
GARCH/GJR β	0.931*** (0.004)	0.924*** (0.005)	--
GJR γ	--	-0.010* (0.005)	--
EGARCH α	--	--	0.117*** (0.006)
EGARCH γ	--	--	0.011*** (0.003)
EGARCH β	--	--	0.982*** (0.003)
Diagnostics			
AIC	13.156	13.155	13.156
BIC	13.161	13.162	13.163
Jarque-Bera [p-value]	1564.11 [0.000]	1487.71. [0.000]	1788.54 [0.000]
Causality *t* test [p-value]	-21.09 [0.000]	-20.49 [0.000]	-22.39 [0.000]

Notes: The dependent variable is US daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 10% levels, respectively.

Table 10: Estimated Conditional Mean (HAR(1,7)) and Conditional Volatility Models for US Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	140.48*** (24.98)	119.30*** (24.41)	80.179*** (20.19)
ϕ_{21}	0.220*** (0.013)	0.216*** (0.012)	0.216*** (0.012)
ϕ_{22}	34524* (19835)	33043 (20292)	35368* (18583)
ϕ_{31}	0.702*** (0.016)	0.702*** (0.016)	0.719*** (0.014)
ϕ_{32}	-36604* (19825)	-34380* (20277)	-35953* (18581)
ω	564.77*** (58.64)	520.97*** (54.36)	0.111*** (0.018)
GARCH/GJR α	0.054*** (0.003)	0.067*** (0.004)	--
GARCH/GJR β	0.926*** (0.004)	0.938*** (0.003)	--
GJR γ	--	-0.051*** (0.005)	--
EGARCH α	--	--	0.078*** (0.005)
EGARCH γ	--	--	0.056*** (0.005)
EGARCH β	--	--	0.983*** (0.002)
Diagnostics			
AIC	12.964	12.958	12.956
BIC	12.972	12.967	12.965
Jarque-Bera [p-value]	2707.3 [0.000]	2511.2 [0.000]	2893.0 [0.000]
Causality F test [p-value]	8.558 [0.000]	4.471 [0.011]	2.674 [0.069]

Notes: The dependent variable is US daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 10% levels, respectively.

Table 11: Estimated Conditional Mean (HAR(1,7,28)) and Conditional Volatility Models for US Daily Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	113.56***	81.332***	55.217***
	(27.10)	(26.87)	(21.21)
ϕ_{21}	0.223***	0.218***	0.215***
	(0.013)	(0.012)	(0.012)
ϕ_{22}	40280*	37333*	17537***
	(21383)	(21857)	(5739.7)
ϕ_{31}	0.627***	0.614***	0.625***
	(0.024)	(0.023)	(0.021)
ϕ_{32}	-51484*	-44400	-16952***
	(26537)	(27046)	(1955.0)
ϕ_{41}	0.085***	0.104***	0.107***
	(0.023)	(0.022)	(0.019)
ϕ_{42}	9555.2	6398.9	-812.81
	(9984.4)	(9815.3)	(5034.4)
ω	499.56***	485.47***	0.113***
	(53.98)	(50.36)	(0.018)
GARCH/GJR α	0.051***	0.064***	--
	(0.003)	(0.003)	
GARCH/GJR β	0.932***	0.942***	--
	(0.003)	(0.003)	
GJR γ	--	-0.052***	--
		(0.005)	
EGARCH α	--	--	0.078***
			(0.005)
EGARCH γ	--	--	0.056***
			(0.004)
EGARCH β	--	--	0.983***
			(0.002)
Diagnostics			
AIC	16.962	12.954	12.952
BIC	12.972	12.965	12.963
Jarque-Bera	2789.1	2601.9	3000.7
[p-value]	[0.000]	[0.000]	[0.000]
Causality F test	3.980	1.491	26.239
[p-value]	[0.008]	[0.215]	[0.000]

Notes: The dependent variable is US daily tourist arrivals to Taiwan. Numbers in parentheses are standard errors.
The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 10% levels, respectively.

Table 12: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for World Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	5517.5*** (1371.4)	6006.3*** (1612)	5094*** (1428)
ϕ_{21}	0.900*** (0.013)	0.894*** (0.015)	0.900*** (0.013)
ϕ_{22}	-14.265 (12.34)	-21.23 (14.09)	-13.83 (12.74)
ω	14164270*** (1435483)	17991048*** (1274676)	8.240*** (1.017)
GARCH/GJR α	0.411*** (0.048)	0.053 (0.038)	--
GARCH/GJR β	0.130** (0.053)	0.094*** (0.036)	--
GJR γ	--	0.637*** (0.110)	--
EGARCH α	--	--	0.539*** (0.059)
EGARCH γ	--	--	-0.228*** (0.042)
EGARCH β	--	--	0.492*** (0.060)
Diagnostics			
AIC	19.882	19.865	19.861
BIC	19.912	19.899	19.895
Jarque-Bera [p-value]	152.38 [0.000]	141.67 [0.000]	132.82 [0.000]
Causality *t* test [p-value]	-1.165 [0.244]	-1.507 [0.132]	-1.086 [0.278]

Notes: The dependent variable is world weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 5% levels, respectively.

Table 13: Estimated Conditional Mean (HAR(1,4)) and Conditional Volatility Models for World Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	3586.6** (1413.7)	3799.2** (1486.7)	3526.94** (1466.2)
ϕ_{21}	0.395*** (0.043)	0.411*** (0.042)	0.416*** (0.042)
ϕ_{22}	315.12*** (110.1)	255.05 (134.03)	283.17** (121.24)
ϕ_{31}	0.543*** (0.044)	0.529*** (0.043)	0.523*** (0.043)
ϕ_{32}	-325.8*** (111.13)	-271.13** (135.05)	-295.83** (121.34)
ω	13573956*** (1061564)	11371174*** (1347635)	9.094*** (1.137)
GARCH/GJR α	0.348*** (0.049)	0.031 (0.032)	--
GARCH/GJR β	0.093*** (0.033)	0.251*** (0.071)	--
GJR γ	--	0.525*** (0.094)	--
EGARCH α	--	--	0.450*** (0.060)
EGARCH γ	--	--	-0.231*** (0.039)
EGARCH β	--	--	0.441*** (0.068)
Diagnostics			
AIC	19.719	19.691	19.703
BIC	19.758	19.736	19.748
Jarque-Bera [p-value]	129.86 [0.000]	136.22 [0.000]	120.71 [0.000]
Causality F test [p-value]	4.398 [0.012]	2.493 [0.083]	3.300 [0.037]

Notes: The dependent variable is world weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and ** denote the estimated coefficients are statistically significant at the 1% and 5% levels, respectively.

Table 14: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for Japanese Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	8461.4*** (861.4)	8416*** (861.1)	8274.8*** (848.7)
ϕ_{21}	0.633*** (0.027)	0.631*** (0.027)	0.631*** (0.026)
ϕ_{22}	-536.81*** (160.7)	-513.8*** (166.6)	-485.5*** (168.9)
ω	1536692*** (538185)	1337882*** (472402)	1.694** (0.625)
GARCH/GJR α	0.104*** (0.026)	0.116*** (0.038)	--
GARCH/GJR β	0.757*** (0.066)	0.782*** (0.059)	--
GJR γ	--	-0.039 (0.043)	--
EGARCH α	--	--	0.185*** (0.041)
EGARCH γ	--	--	0.045* (0.026)
EGARCH β	--	--	0.886*** (0.040)
Diagnostics			
AIC	19.040	19.041	19.045
BIC	19.069	19.075	19.080
Jarque-Bera [p-value]	18.589 [0.000]	19.244 [0.000]	17.293 [0.000]
Causality *t* test [p-value]	-3.339 [0.000]	-3.084 [0.002]	-2.874 [0.004]

Notes: The dependent variable is Japanese weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and * denote the estimated coefficients are statistically significant at the 1% and 10% levels, respectively.

Table 15: Estimated Conditional Mean (HAR(1,4)) and Conditional Volatility Models for Japanese Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	4221.7*** (928.25)	4043.5*** (918.3)	3686.3*** (933.8)
ϕ_{21}	0.297*** (0.041)	0.288*** (0.041)	0.284*** (0.039)
ϕ_{22}	1247.7 (1974.4)	1999.8 (2000.0)	905.48 (1516.7)
ϕ_{31}	0.520*** (0.051)	0.536*** (0.051)	0.550*** (0.049)
ϕ_{32}	-1502.5 (1979.0)	-1483.7 (2005.3)	-1123.8 (1537.2)
ω	1439261*** (473454)	1660438*** (567711)	1.486*** (0.152)
GARCH/GJR α	0.108*** (0.026)	0.081** (0.036)	--
GARCH/GJR β	0.746*** (0.064)	0.718*** (0.076)	--
GJR γ	--	0.070 (0.052)	--
EGARCH α	--	--	0.202*** (0.035)
EGARCH γ	--	--	-0.037 (0.030)
EGARCH β	--	--	0.898*** (0.010)
Diagnostics			
AIC	18.926	18.927	18.934
BIC	18.966	18.971	18.979
Jarque-Bera [p-value]	30.196 [0.000]	24.524 [0.000]	29.765 [0.000]
Causality F test [p-value]	0.485 [0.487]	1.732 [0.178]	1.193 [0.304]

Notes: The dependent variable is Japanese weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors. The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** and ** denote the estimated coefficients are statistically significant at the 1% and 5% levels, respectively.

Table 16: Estimated Conditional Mean (HAR(1)) and Conditional Volatility Models for US Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	3434.8*** (395.06)	2663.4*** (324.62)	2639.5*** (289.74)
ϕ_{21}	0.751*** (0.022)	0.799*** (0.020)	0.795*** (0.019)
ϕ_{22}	-56075*** (8521.3)	-40623*** (7081.7)	-39491*** (6248.4)
ω	269004*** (38322)	229228*** (35754)	3.614*** (0.687)
GARCH/GJR α	0.352*** (0.045)	0.650*** (0.101)	--
GARCH/GJR β	0.298*** (0.647)	0.366*** (0.063)	--
GJR γ	--	-0.588*** (0.104)	--
EGARCH α	--	--	0.436*** (0.055)
EGARCH γ	--	--	0.257*** (0.039)
EGARCH β	--	--	0.703*** (0.052)
Diagnostics			
AIC	16.206	16.152	16.156
BIC	16.235	16.187	16.190
Jarque-Bera [p-value]	96.256 [0.000]	58.224 [0.000]	46.853 [0.000]
Causality *t* test [p-value]	-6.581 [0.000]	-5.736 [0.000]	-6.320 [0.000]

Notes: The dependent variable is US weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors.
The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficients are statistically significant at the 1% level.

Table 17: Estimated Conditional Mean (HAR(1,4)) and Conditional Volatility Models for US Weekly Tourist Arrivals to Taiwan

Parameters	GARCH	GJR	EGARCH
ϕ_1	2938.7*** (436.0)	2005.8*** (340.09)	2211.7*** (276.58)
ϕ_{21}	0.599*** (0.042)	0.649*** (0.040)	0.631*** (0.037)
ϕ_{22}	-88327 (117927)	33962 (105877)	24106 (93349)
ϕ_{31}	0.190*** (0.048)	0.195*** (0.044)	0.195*** (0.043)
ϕ_{32}	39958 (118778)	-63512 (106703)	-56670 (94025)
ω	306325*** (41333)	271886*** (39812)	4.680*** (0.825)
GARCH/GJR α	0.343*** (0.047)	0.648*** (0.107)	--
GARCH/GJR β	0.236*** (0.070)	0.300*** (0.072)	--
GJR γ	--	-0.614*** (0.108)	
EGARCH α	--	--	0.431*** (0.052)
EGARCH γ	--	--	0.280*** (0.038)
EGARCH β	--	--	0.623*** (0.063)
Diagnostics			
AIC	16.188	16.130	16.134
BIC	16.228	16.175	16.178
Jarque-Bera [p-value]	89.944 [0.000]	55.315 [0.000]	49.175 [0.000]
Causality F test [p-value]	14.630 [0.000]	8.073 [0.000]	15.763 [0.000]

Notes: The dependent variable is US weekly tourist arrivals to Taiwan. Numbers in parentheses are standard errors.
The log-moment condition is necessarily satisfied as the second moment condition is satisfied.
AIC and BIC denote the Akaike Information Criterion and Schwarz Bayesian Information Criterion, respectively.
*** denotes the estimated coefficient is statistically significant at the 1% level.

Table 18. Summary of HAR Effects Under Temporal Aggregation

Tourist Arrivals	Daily Lags		
	1	**1, 7**	**1, 7, 28**
World	√	√	X
Japan	√	√	√
USA	√	√	√

Note: 1, 7 and 28 lags refer to days.

Tourist Arrivals	Weekly Lags	
	1	**1, 4**
World	√	√
Japan	√	√
USA	√	√

Note: 1 and 4 lags refer to weeks.

Table 19. Summary of Asymmetry and Leverage Effects Under Temporal Aggregation

Tourist Arrivals	Daily Lags		
	1	**1, 7**	**1, 7, 28**
World	Asymmetry	Symmetry	Symmetry
Japan	Asymmetry	Asymmetry	Asymmetry
USA	Asymmetry	Asymmetry	Asymmetry

Note: Asymmetric effects for the GJR and EGARCH models were consistent in each case at the 1% and 5% significance levels.

Tourist Arrivals	Weekly Lags	
	1	**1, 4**
World	Asymmetry	Asymmetry
Japan	Symmetry	Symmetry
USA	Asymmetry	Asymmetry

Note: Asymmetric effects for the GJR and EGARCH models were consistent in each case at the 1% and 5% significance levels.

Table 20

Summary of Negative Price and Exchange Rate Effects Under Temporal Aggregation

Tourist Arrivals	Daily Lags		
	1	1, 7	1, 7, 28
World	3/3	3/6	5/9
Japan	3/3	3/6	6/9
USA	3/3	3/6	4/9

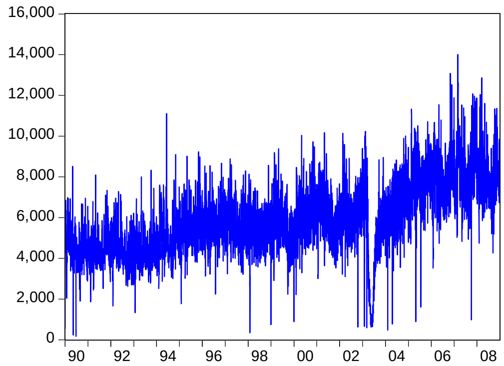
Note: The entry denotes the number of times the three models give negative price and exchange rate effects relative to the total number of such effects.

Tourist Arrivals	Weekly Lags	
	1	1, 4
World	3/3	3/6
Japan	3/3	3/6
USA	3/3	3/6

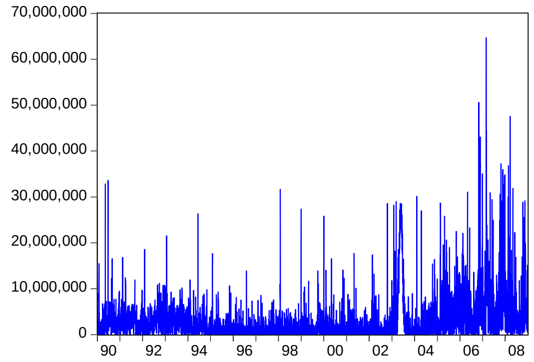
Note: The entry denotes the number of times the three models give negative price and exchange rate effects relative to the total number of such effects.

Figure 1. Daily Tourist Arrivals to Taiwan and Volatility

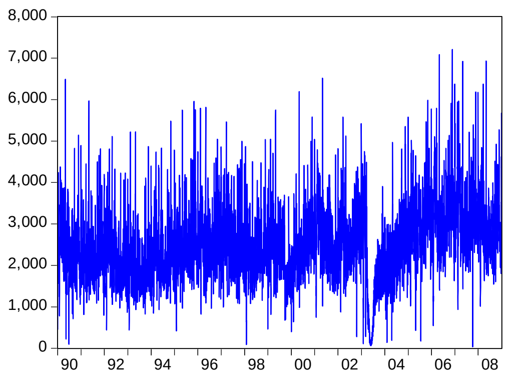
Daily World Tourists



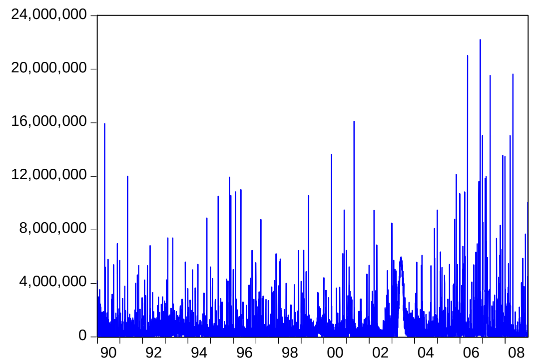
Volatility Daily World Tourists



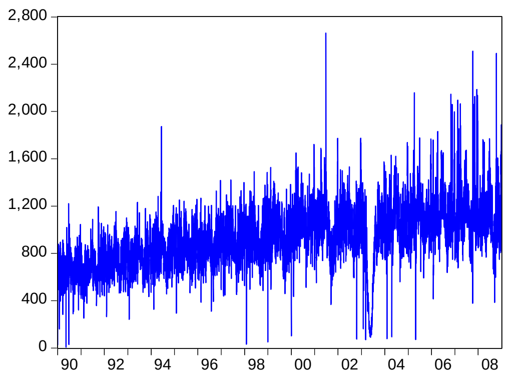
Daily Japanese Tourists



Volatility Daily Japanese Tourists



Daily US Tourists



Volatility Daily US Tourists

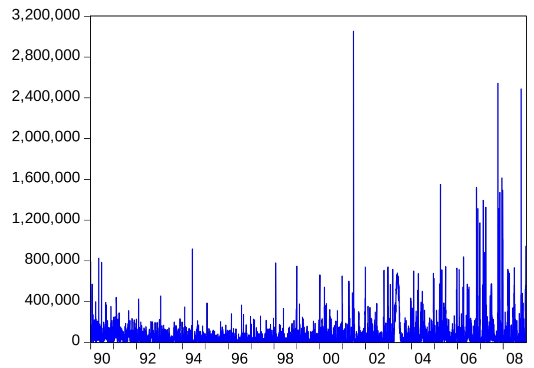


Figure 2. Weekly Tourist Arrivals to Taiwan and Volatility

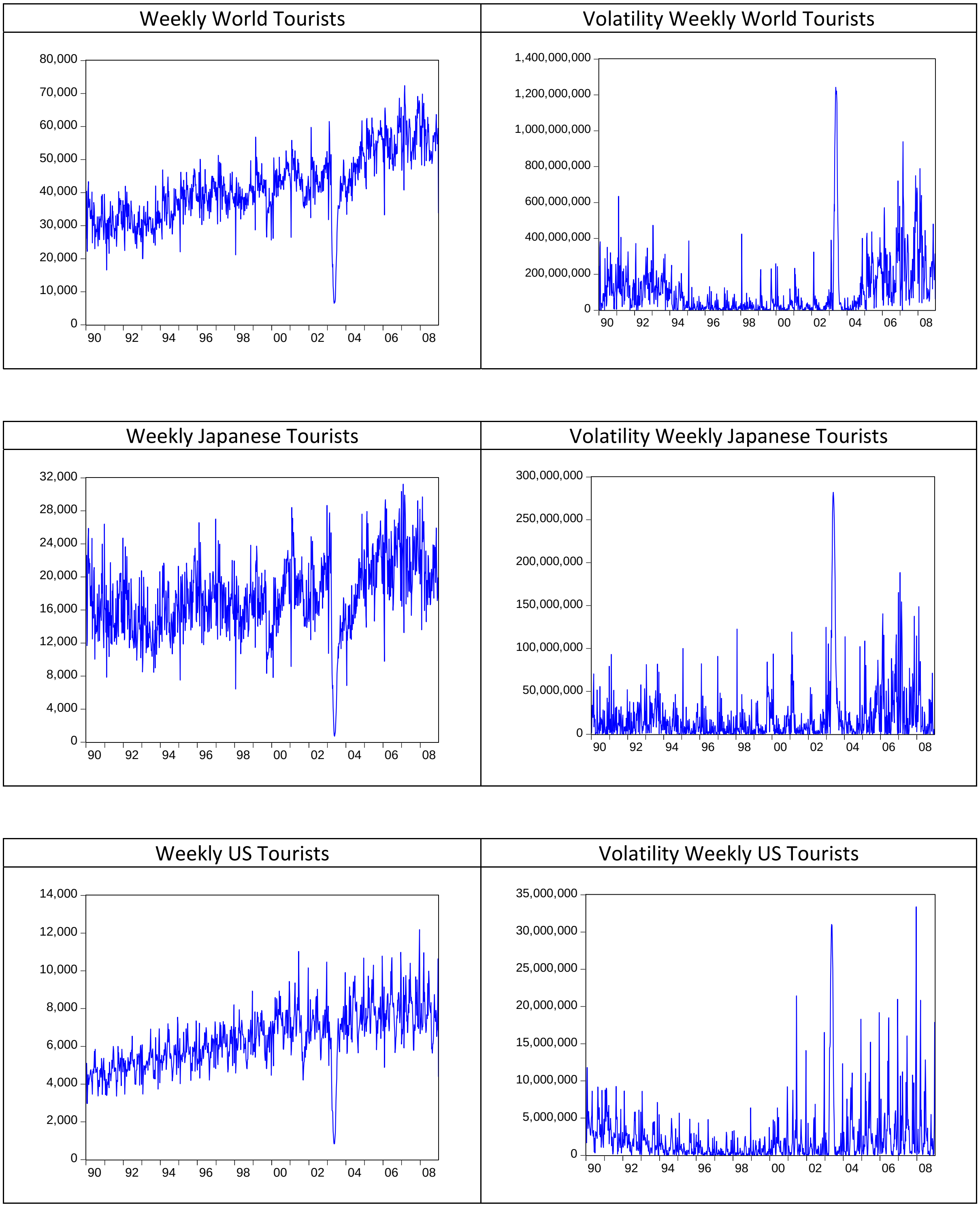


Figure 3. Daily Exchange Rates and Volatility

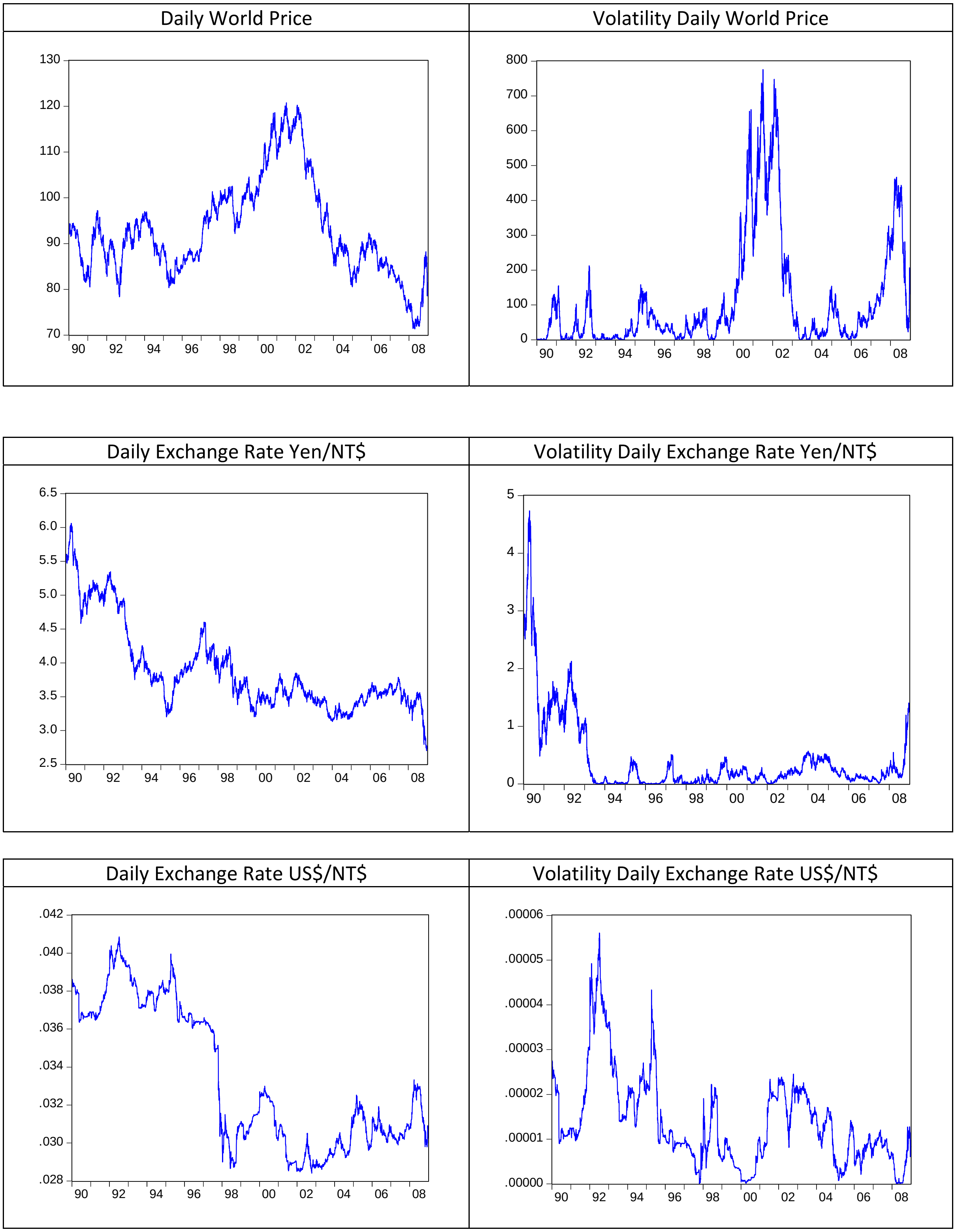


Figure 4. Weekly Exchange Rates and Volatility